Wisconsin Highway Research Program

Analysis and Feasibility of Asphalt Pavement Performance-Based Specifications for WisDOT

Wisconsin Highway Research Program
LIMITED USE DOCUMENT

University of Wisconsin - Madison

Revised July 30, 2014

Summary Page

Project Title:	Analysis and Feasibility of Asphalt Pavement – Performance Based Testing Specifications for WisDOT
Proposing Agency:	The Board of Regents of the University of Wisconsin System University of Wisconsin-Madison Office of Research and Sponsored Programs 21 N. Park St., Suite 6401 Madison, WI 53715-218 608-262-3822
Person Submitting the Proposal:	Pouya Teymourpour
Proposal Written By:	Andrew Hanz, Ph.D. Pouya Teymourpour Erik Lyngdal Professor Hussain U. Bahia
Proposal Date:	January 24, 2013
Principal Investigator:	Hussain U. Bahia Professor Department of Civil and Environmental Engineering 3350 Engineering Hall 1415 Engineering Dr. Madison, WI 53706
Administrative Officer:	Kim Moreland Director of Research & Sponsored Programs 21 N. Park St., Suite 6401 Madison, WI 53715-218 608-262-3822
Proposed Contract Period:	18 months
Total Contract Amount:	$200,000
Indirect Cost Portion at:	15%

Table of Contents

1. Background

Hot-Mix Asphalt research activities following the implementation of SuperPave have introduced numerous technological advances in terms of mixture composition, materials characterization, and pavement design, developed with the intent to both improve in-service performance and reduce the environmental impacts of construction. These three focus areas are interconnected, as improved methods for materials characterization provide a means to evaluate new mix design concepts and serve as inputs to pavement design methods. Furthermore, the new test methods available have been found to correlate well to in-service performance due to their ability to simulate temperature, loading times, and aging levels experienced in the field. In regards to improvements in mixture composition, advanced material characterization methods provide the ability to quantify the performance benefits of modified asphalts and provide a performance related basis for defining optimum use of recycled materials in HMA mixes and the potential temperature reduction for WMA technologies.

While the current state of technology has experienced significant advances, methods of mix design and production acceptance remain relatively unchanged from a state agency perspective. In general, mixes are designed based on volumetric criteria and controlled through monitoring of both the volumetric properties of production samples and the density achieved during field compaction. Given the increased complexity of mixes currently being produced, including WMA, mixes with high recycle content, etc. and the fact that mixes accepted under the current specification framework exhibit varying levels of distress while in-service, there is potential that acceptance based solely on volumetric criteria is not sufficient to ensure adequate performance.

To maintain the current WisDOT protocols for sampling and evaluation during production it is necessary to investigate surrogate measures of performance as frequent performance testing is not feasible due to the time and equipment required to conduct the tests. To address this challenge new visualization and measurement techniques capable of quantifying the shear forces experienced and aggregate structure achieved during compaction have been identified as candidate methods for quality control/acceptance. As a result the general concept for a performance-based HMA evaluation framework used in this study will provide both performance tests intended to be used during the mix design phase and surrogate measures of performance to monitor mixture quality during production.

2. Objectives

The aim of this research is develop a performance-based acceptance framework that applies to both mixture design and quality control/acceptance during production and further to assess the feasibility of implementing this framework into current WisDOT practice. To achieve this goal, the following objectives have been established:

- Develop criteria for selection of candidate test methods and a process for prioritizing which properties will be measured in the performance-based HMA evaluation framework.
- Identify and validate surrogate measures of performance for use during production and acceptance testing.
- Quantify the benefits and identify the challenges of implementing a performance-based framework of mix acceptance through comparison of outcomes to current practice.

3. Detailed Work Plan

To be considered a viable system the performance based evaluation framework must address all aspects of HMA specifically, mix design, production, and in-place evaluation. In current practice materials are evaluated in these areas using volumetric criteria, moisture damage resistance testing, and in-place density measurement. The proposed framework intends to include mixture performance tests in the mix design phase and surrogate measures of these tests in the production control and in-place evaluation phases of HMA acceptance.

3.1. Task 1: Development of a Decision Framework and Selection of Candidate Test Methods

3.1.1. Mixture Performance Testing

Candidate test methods will be identified through a detailed literature review to define the current state of practice at both the state and national level. In addition, the current state of research will be defined through review of journal articles and recent reports published by NCHRP, WHRP, and other state based research programs. Examples of recent research articles that will be reviewed include the proceedings of the "Leading Edge Workshop" held as part of the 2013 AAPT meeting, recent WHRP reports focused on evaluation of the dynamic modulus and Flow Number tests, and the final report for TPF-5(132) which was a pooled fund study investigating Low Temperature Cracking funded by MnDOT (1), (2) (3) (4). It should be noted that members of the research team participated in this pooled fund project. A preliminary summary of the performance tests available, classified by performance characteristic is provided in Table 3-1, additional tests may be added based on the literature review results.

Table 3-1: Preliminary Summary of Test Methods Available Classified by Performance Characteristic

Performance Characteristic	Performance Tests Available
Rutting Resistance	Repeated Load Permanent Deformation Test (AASHTO TP-79), Wheel Tracking Tests (AASHTO T324)
Moisture Damage Resistance	Resistance to Moisture Damage (AASHTO T-283) Wheel Tracking in Wet Condition
Resistance to Fatigue Cracking	Beam Fatigue (AASHTO T-321), Overlay Tester, Semi-Circular Bend Test , Uniaxial Fatigue (Push Pull), Indirect Tension Test
Resistance to Thermal Cracking	Indirect Tension Strength/Creep-Compliance, Direct Compact Tension Test (DCT), Semi-Circular Bend Test, Asphalt Thermal Cracking Analyzer (ATCA)
Pavement Design Input	Dynamic Modulus (AASHTO TP-62)

As shown in Table 3-1, it is well established that numerous test methods are available to evaluate all aspects of performance, therefore it was deemed necessary by the research team to include review of current state practice in the literature search to identify performance tests and specification limits that have been implemented by other states as an additional search criterion.

3.1.2. Production and In-Place Testing

The aforementioned performance tests are most appropriate for the mix design phase due to the equipment, time, and sample preparation required. To compliment these tests it is necessary to establish surrogate measures of performance that are more suited evaluation of material during production or after placement. A summary of candidate test methods including potential applications is provided in Table 3-2, in addition to these tests the Non-Destructive Testing Report recently published by WHRP will be reviewed to identify any promising test methods (4).

Table 3-2: **Summary of Candidate Test Methods for Production and In-Place Testing and Sample Needs**

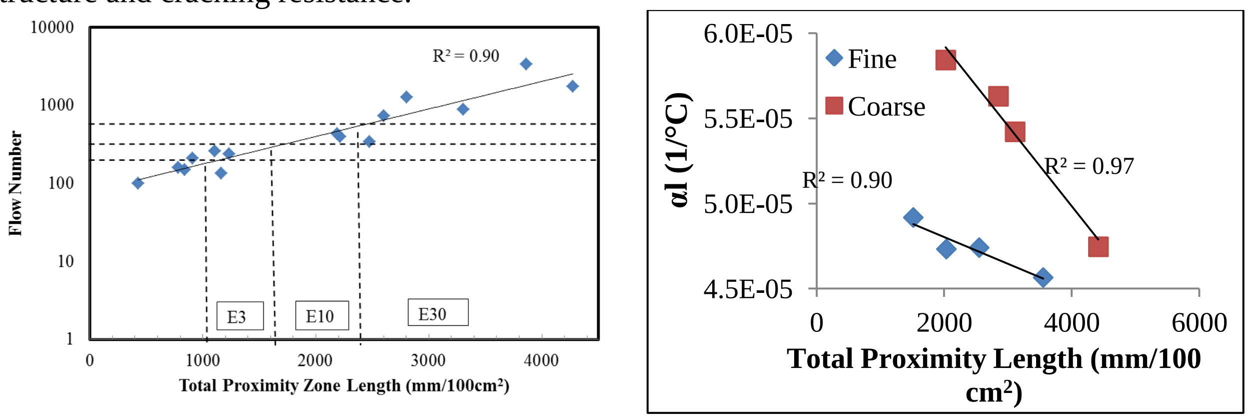
Candidate Test Method	Test Output	Potential Applications	
		Production Control	In-Place Testing
Aggregate Structure Analysis by Planar Imaging	Total Contact Length	Sample cutting required.	Coring required
Gyratory Pressure Distribution Analyzer (GPDA)	Mixture Shear Resistance	Yes, no impact to current practice	N/A
Small Sample Performance Evaluation	Dynamic Modulus	N/A	Coring required

The tests summarized in Table 3-2 include two surrogate measures of performance and a procedure for measuring the dynamic modulus and fatigue on small samples recently published by Xin et. al. at the Turner Fairbank Research Center (5). The surrogate measures selected, planar image analysis and shear resistance measurement, were recently developed by UW-MARC as a products of the Asphalt Research Consortium, both tests are in the process of standardization through AASHTO (Imaging) or ASTM (GPDA). To be deemed viable a relationship must exist between the surrogate measures selected and mixture performance testing, previous research indicates that both of the selected tests meet this requirement. The following is a brief summary of the method and relationships developed with mixture performance.

Aggregate Structure Analysis Using Digital Imaging

Aggregate structure is quantified by processing of a scanned image of a sliced HMA mix sample using the Image Processing and Analysis (IPas^2) (6). The image processing step includes many well established filters to convert the scanned image to a binary (black/white) image. The image is then analyzed to identify aggregates that are in contact and the length of contact between aggregates. The output of this visualization tool is the total proximity length, which is a measure of aggregate structure. The details of this filtering and analysis were recently summarized in draft AASHTO format and submitted to FHWA for consideration.

The proximity length parameter provided as the output of visual analysis is a direct measure of the quality of aggregate structure developed during compaction. Conceptually, higher aggregate packing (superior aggregate structure) reduces the strain level applied to the asphalt binder/mastic phase of the mixture and thus results in improved performance. Comparison to laboratory mixture performance tests to relate aggregate structure to rutting resistance as measured by the Flow Number test and mixture thermo-volumetric properties as measured by the ATCA device provided in Figure 3-1 confirm the relationship between aggregate structure and performance. The research team will investigate extending this concept to relating aggregate structure and cracking resistance.



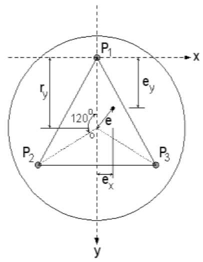
(a) **(b)**

Figure 3-1: Examples of Relationships between Aggregate Structure and Flow Number (6) **(a), and Coefficient of Thermal Expansion** (7) **(b)**

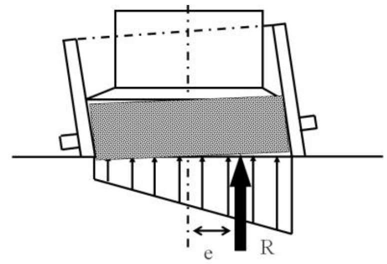
Potential applications of aggregate structure parameters measured by IPas^2 include both testing during production and evaluation of in-service pavements. An additional benefit of application of this product to field cores is that it provides a direct measure of the aggregate structure achieved during field compaction, rather than relying on volumetric properties or laboratory compacted samples to make inferences regarding performance.

Mixture Internal Friction Measurement

The Gyratory Pressure Distribution Analyzer (GPDA) provides a means to evaluate the internal mixture resistance to shear distortion. To define shear resistive forces the device measures the resultant load and it's eccentricity from the center-line during compaction through triangulation of the response of three load cells. Previous research suggests that mixes with resultant loads located further from the center line (higher "e" values) result in more stable HMA mixes. The schematic is adapted directly from the draft ASTM standard for the device current under consideration. A schematic of the plate and the resultant force imparted by the mixture during compaction is provided in Figure 3-1. The schematic is adapted directly from the draft ASTM standard for the device current under consideration



(a)



(b)

Figure 3-2: Shop Drawing of GPDA Plate (a) and Schematic of Mixture Resistive Forces During Compaction (b)

The GPDA device was applied previously in WHRP research to evaluate mixture workability and stability using indices that combined shear force measurements with volumetric properties. Result found that the Traffic Force Index, which was used to define mixture stability in the study correlated well with rutting resistance (8). Related research found shear resistance measurements were more sensitive to changes in mix proportions (i.e. gradation and asphalt content) than conventional volumetric measurements, as the GPDA plate successfully identified mixes that collapsed due to excessive binder content or low fine aggregate angularity (9). This finding directly relates to the vision for use of the GPDA in the performance-based framework as a tool to provide real-time measurements of shear resistance during production based on measurements taken during sample compaction.

3.1.3. Components of the Decision Framework for Performance-Based Specifications

Potential technical evaluation criteria including justification for criteria and examples of their application are provided in Table 3-3, it is proposed to select candidate tests based on the status of standardization of the test method and potential for implementation for WisDOT. In addition to technical considerations, it is also necessary to include the practical aspects of the test in the decision making process. Specific evaluation parameters include equipment cost, difficult in sample preparation, and the ability to use the same equipment to conduct multiple test procedures will be considered.

Table 3-3: Technical Criteria Identified for Technical Evaluation of Candidate Test Methods

Evaluation Criteria	Justification	Examples
Specified by other state agencies	Leverage research and implementation activities of other states.	• TxDOT use of the Hamburg • MnDOT use of DCT (3)
Standardized test procedure	Implementation of tests recognized by AASHTO is preferred by WisDOT.	Majority of test methods in Table 3-1 are existing or provisional test methods.
Precision and Bias statement available?	Established P&B allows for better differentiation between test variability and effects of materials.	P&B data available for Flow Number and Dynamic Modulus tests (10)
Critical pavement distresses experienced in WI	• Enhance benefit to WisDOT. • Optimize number of tests required.	• Most WI pavements fail due to load or thermal induced cracking. • Rutting and moisture damage failures are rare.
WisDOT Initiatives	Provide research results that will support other WisDOT areas.	• Darwin ME Deployment. • Green Team priorities

The research project will develop a detailed process for selecting candidate test methods through consideration of both qualitative observations and quantitative factors, such as cost or time constraints. The research team will propose discussion of the decision making process as a primary agenda item for the project kick-off meeting to ensure that both the state agency and industry perspective represented on the TOC is included.

3.2. Task 2: Work Plan Development

The main objectives of the work plan are first to evaluate the ability of the candidate test methods to discriminate between mixes representative of the materials and production variation representative of current practice in Wisconsin. The second objective is to establish relationships between laboratory performance tests and surrogate test measures to assess potential applications of production level/in-place test procedures. To meet the objectives three experiments were designed, as summarized below.

3.2.1. Experiment 1: Evaluation of Mixes that Meet Current Specifications

The objective of this experiment is to evaluate the sensitivity of selected mixture performance and production/in-place acceptance tests on changes in materials and differing levels of binder replacement. To conduct this evaluation three base mixtures will be used, 100% virgin aggregate (control), 15% RAP Binder replacement, and 50% RAP binder replacement. The levels of binder replacement represent the current state average for HMA mixes and a “high RAP” mix respectively. To remove confounding factors, all mixes will be designed to similar levels of VMA. A preliminary experimental design including justification for each factor is presented in Table 3-3. In addition to the factors presented, the research team will consider adding additional mix design traffic levels in the final experiment.

Table 3-4: Preliminary Experimental Design for Experiment 1

Factor	Levels	Basis for Selection
Mix Designs (3)	100% Virgin Aggregate 15% Recycled Binder Replacement 50% Recycled Binder Replacement	Base mixes selected by research team for this portion of the study.
Aggregate Source (up to 4)	Cisler, Wimmie, Christian-Gade, Glenmore	Maintain consistency with previous WHRP projects (i.e. 08-06, 09-01, 10-07, 14-06).
PG Grade (up to 3)	Conventional grade and two levels of modification	Establish performance impacts of modification.
ESAL Level (1)	E-10, will consider other levels in final experimental plan.	Performance related testing most appropriate for high traffic pavements.

3.2.2. Experiment 2: Sensitivity of Performance Parameters to Production Tolerances

This experiment will establish the sensitivity of the selected performance tests to variations in production and compare the variation due to changes in materials with the inherent variability of a given test procedure. WHRP funded a similar study to investigate this aspect of the Flow Number test in project 0092-09-01 (1). The proposed experiment will use the three base mix designs with one aggregate type and a minimum two binder grades from the experimental design provided in Table 3-4. To investigate the effects of production variability, the research team will select mixture proportions or volumetric properties to vary, potential factors include: % Air Voids, VMA, %AC, P4, P200, etc. The factors selected will be varied by at least three levels, design, within, and outside current production tolerances. The initial approach to choosing production factors and how they are varied will be determined based on literature review of the effects of mix design factors on cracking potential, as cracking is the most common distress in Wisconsin and thus it is important that cracking tests be sensitive to JMF changes.

Similar to the approach stated previously, the experiment designed will be applied to both mixture performance and production level tests. It is expected that significant variation will be observed due to varying production factors. In order to better explain observed trends, component tests will be considered. As an example, mastic viscosity testing will be applied to further assess the effects of variation in asphalt and filler content (D:B ratio) on test results. Recent research indicates that mastic viscosity directly relates to the quality of aggregate structure formed during compaction, and thus overall mixture performance (6). An example of this relationship for two gradations and multiple asphalt binders are presented in Figure 3-3. It is envisioned that the mastic viscosity or data from other component tests selected will serve as supplemental information that will enhance the quality of the analysis conducted in the experiment.

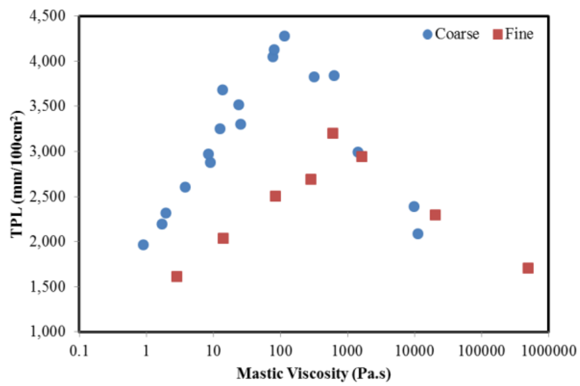


Figure 3-3: Relationship Between Mastic Viscosity and Aggregate Structure (6)

.

3.2.3. Experiment 3: Development of Supplemental Guidelines for Required Performance Testing for High Recycled Content Mixes

To meet the needs of WisDOT for using more and different types of recycled materials it is necessary to develop a methodology to ensure the quality of mixes containing high recycled content. The objective is to propose a framework similar to what is provided in Section 460.2.5 for determining what performance tests are needed to evaluate mixes with high recycled content and at what levels of binder replacement they are warranted. The experiment will leverage a subset of the results collected as part of the experiment detailed in Table 3-4. In addition, to these factors multiple RAP/RAS proportions for each recycled mix will be considered. For the first experiment, regardless of recycled material content the base binder PG grade will be held constant for all materials combinations. Performance evaluation will focus on resistance to fatigue and thermal cracking evaluated after both short and long-term oven aging.

Similar to the previous experiment, component tests will be used to provide supplemental information to aide in the decision process. In this experiment, composite binder performance grade will be evaluated using two methods to establish the relationship between recycled material combinations and change in PG grade. This relationship will be used to identify RAP/RAS combinations that use of a softer base asphalt, the specific criteria used to make this determination will be defined in the detailed experimental plan based on review of current research, WisDOT specifications, and other northern state practices. The grading methods selected are the blending charts based on extracted/recovered recycled binders as conducted in WHRP project 0092-10-06 and a mortar grading procedure conducted as part of the Asphalt Research Consortium (11), (12). The mortar grading procedure is a draft AASHTO standard and was selected because it eliminates the need for use of solvents and is representative of the actual blending that occurs between materials.

For the RAP/RAS combinations identified as requiring a softer base asphalt, two courses of action will be investigated: reducing the base binder PG grade and using an extender oil, with the grade change or concentration of extender oil used determined based on the performance related criteria established through binder grading results. Mixes will be prepared and tested for resistance to fatigue and thermal cracking at two aging conditions to provide a direct evaluation of the effectiveness of each treatment.

3.2.1. In-Service Field Validation

The research team will coordinate with WisDOT to identify a total of 10 pairs of projects (20 total) with similar environmental and traffic conditions but differing levels of performance. For each project sufficient cores will be taken for evaluation of aggregate structure and testing of mechanical performance. Specific mechanical performance tests available for this analysis will be selected based on a review of recent research related to evaluation of the mechanical properties of small specimens and the results of Task 3.1. This task provides an opportunity for initial validation of both the selected performance tests and aggregate structure evaluation by comparing the rankings obtained from these methods with in-service performance. As stated in the RFP, the research team will rely on WisDOT to provide the pavement cores.

3.3. Task 3: Interim Presentation and Project Memorandum

The research team will prepare a project memorandum that summarizes the results of Task 1 and presents the detailed experimental plan for conduct of the research one month prior to the scheduled POC meeting. To facilitate review, the document will be a maximum of 25 pages. In regards to Task 1, the focus will be on the results of the literature review, WisDOT pavement distress survey, and the approach used to select the candidate test methods. Justification for the test methods selected will also be provided. A summary presentation will be given to the POC and the research team will address all comments received in development of the final work plan. The research team will request POC approval prior to proceeding with the work plan.

3.4. Task 4: Execution of Work Plan

The majority of the project timeline will be dedicated to execution of the POC approved work plan. Preliminary focus areas of the analysis developed based on preparation of this proposal include:

- Establishing the sensitivity of the selected performance tests and production evaluation methods to materials representative of those currently used in Wisconsin mixes.
- Understanding the variability of selected test methods relative to the effects of blend changes representative of normal production variation in Wisconsin.
- Development of a performance related framework for evaluating mixes with high recycled material contents that includes guidance as to when performance testing is necessary and is capable of identifying effective means for improving the durability of high recycle mixes.
- Application of component tests, including mastic viscosity, RAP/RAS mortar grading, and grading based on extraction and recovery to improve understanding of observed trends.
- Quantifying the benefit of transitioning to a performance based system through comparison to current practice.

3.5. Task 5: Project Deliverables and Closeout Activities

The research team will summarize the results of Tasks 1-4 in a draft final report submitted three months prior to the project end date (November 1, 2015) for TOC review and will present findings to the TOC in Spring 2015. Any written comments received prior to the project close-out presentation will be addressed in the TOC meeting. The report will be finalized based on written comments and discussion during the meeting. The research team is committed to coordinating with the TOC to receive approval of the Final Report.

4. Anticipated Research Results and Implementation Plan

This research project has potential to impact current practice through revisions to specifications and introduction of new test methods to better relate mixture design and acceptance testing to in-service performance. A tentative list of changes to specifications is summarized in Table 4-1. It should be noted that proposing potential specification limits is beyond the scope of this study, therefore any recommendations for inclusion of additional tests will be "Report Only" to aide WisDOT in piloting the new framework.

Table 4-1: Potential Specification Changes Resulting From Research Findings

WisDOT Guidance Document	Section	Potential Change
Standard Specifications	460 – Table 460.2	Include selected performance tests as a "report only" to pilot performance based testing framework
	460.2.5	Decrease in %Binder Replacement maximums and different limits for RAP/RAS for surface courses.
	460.2.6	Addition of mortar grading procedure as an alternative to conventional extraction and recovery.
	460.2.8	• Required contractor and department testing (i.e. GPDA/Imaging) • Change in production tolerances for %AC, %Air Voids, and/or %VMA.
	460.3.3	Report only for output of selected in-place measurement tool.
Construction Materials Manual	8-36.6	Inclusion of test methods proposed in this study for both mix design and production/in-place evaluation.
	8-36.6.16	Revised procedures for evaluation of RAP/RAS.

The aforementioned changes are envisioned as an end result of this effort, that will be realized after WisDOT has sufficient information for development of specification limits and other logistical aspects of full deployment. It is recommended that the next step in maturation of this process is a pilot project. A product of this research will be to facilitate this process through development of a draft "Strawman" specification framework with detailed test procedures for use as a guidance document.

This research will also prepare a detailed proposal for the parameters and oversight of the pilot project aimed at development of the performance related framework. The proposal will include a detailed estimate of cost and time associated with a performance based specification framework. The proposal will also recommend a time-frame for completion of the pilot project and potential benchmarks for WisDOT to evaluate progress.

5. Project Schedule and Time Requirements

The total project duration is 18 months, consisting of 15 months for research and an additional 3 months for review and approval of final project deliverables. The anticipated start date is August 1, 2014 and the anticipated end date is February 1, 2016. Based on this timeframe, the project schedule is provided in Table 5-1. The proposed schedule for TOC meetings and submission of deliverables are denoted by the codes D and M. In addition to the deliverables provided in the schedule, the research team will submit quarterly reports according to WisDOT guidelines.

Table 5-1: Project Schedule

Task	Quarter						
	1	2	3	4	5	6	7
	8/14-9/14	10/14-12/14	1/15-3/15	4/15-6/15	7/15-9/15	10/15-12/15	1/16-2/16
1. Synthesis of Current Research	M1						
2. Work Plan Development							
3. Interim Presentation and Project Memorandum		D1,M2					
4. Execution of Work Plan and Analysis of Results							
5. Project Deliverables						D2	
6. Project Closeout							D3,M3

Summary of Deliverable and Meeting Codes:

- **M1:** Project kick-off meeting held with Project Oversight Committee
- **D1, M2:** Project memorandum and interim presentation at full TOC meeting.
- **D2:** Submission of draft final report and other project deliverables as identified in Task 5.
- **D3, M3:** Project closeout presentation to full TOC and delivery of final report.

A research team consisting of UW-MARC staff and students was assembled based on past experience and areas of study to meet the technical requirements of the project according to the schedule provided above. The research team and their involvement in the project is described in Table 5-2.

Table 5-2: Summary of Research Team and Responsibilities

Team Member	Role	Responsibilities
Andrew Hanz	Researcher	• Project Management and Reporting • Communication with TOC • Detailed Analysis of Data • Preparation of Project Deliverables
Pouya Teymourpour	Researcher	• Evaluation of candidate mixture performance tests. • Evaluation of production tests (i.e. imaging and GPDA). • Oversight of mechanical testing. • Data Analysis and Reporting.
Hussain Bahia	Principal Investigator	• Development of Work Plan • Oversight of Data Analysis • Review of Project Deliverables • Development of Implementation Plan

In addition to the personnel listed in Table 5-2, graduate student and the support of undergraduate hourly staff was budgeted to support materials testing and sample preparation. The distribution of hours by task for the project team is provided in Table 5-3.

Table 5-3: Project Team – Distribution of Hours by Task

INDIVIDUALS	TASKS					TOTAL HOURS
	1	2	3	4	5	
Principal Investigator: Hussain Bahia	16	63	63	79	94	315
Researcher: Andrew Hanz	18	70	53	88	121	350
Researcher: Pouya Teymourpour	52	209	157	367	262	1047
Graduate Students/Senior Staff	236	393	79	549	315	1572
Hourly Students/Junior Staff	0	300	0	700	0	1000
TOTALS	**322**	**1035**	**352**	**1783**	**792**	**4284**

6. Project Budget

Table 1 Work Effort by Task

INDIVIDUALS	TASKS 1	2	3	4	5	Total Salaries	Fringes	Total Salaries and Fringes
Principal Investigator: Hussain Bahia	$ 1,391	$ 5,594	$ 5,538	$ 6,957	$ 8,349	$ 27,829	$ 9,378	$ 37,207
Graduate Students/Senior Staff	$ 5,877	$ 12,289	$ 4,809	$ 18,690	$ 11,764	$ 53,428	$ 13,090	$ 66,518
Hourly Students/Junior Staff	$ -	$ 3,000.00	$ -	$ 7,000.00	$ -	$ 10,000	$ 400	$ 10,400
TOTALS	$ 7,269	$ 20,882	$ 10,347	$ 32,648	$ 20,113	$ 91,257	$ 22,869	$ 114,126

Table 2 Total Contract Summary by Fiscal Year

	1	2	3	4	5	Year 1*	Year 2	TOTALS
Total Salaries, Wages and Fringes (From Table 1)	$ 9,178	$ 25,898	$ 13,391	$ 39,851	$ 25,808	$73,893	$40,233	$114,126
Sub-Contracts (Please list each subcontract seperately)								
Subcontractor 1: Andrew Hanz	$ 1,785	$ 7,035	$ 5,285	$ 8,750	$ 12,145	$15,095	$19,905	$ 35,000.00
Subcontractor 2 (Provide Name)								$ -
Subtotal	$ 1,785	$ 7,035	$ 5,285	$ 8,750	$ 12,145	$ 15,095	$ 19,905	$ 35,000.00
Other Direct Costs								
Item 1: Computer Services	$ -	$ 800	$ 200	$ 800	$ 200	$1,000	$1,000	$ 2,000
Item 2: Tuition Remission	$ 2,000	$ 2,001	$ 2,000	$ 2,001	$ 2,001	$ 6,669	$3,334	$ 10,003
Item 3								$ -
Subtotal	$ 2,000	$ 2,801	$ 2,200	$ 2,801	$ 2,201	$ 7,669	$ 4,334	$ 12,003
Materials & Supplies (List all items over $1000 seperately)								
Item 1: Containers and Shipping	$ -	$ 2,500	$ -	$ 750	$ -	$ 2,500	$ 750	$ 3,250
Item 2: Materials for Sample Performance Test Preparation	$ -	$ 1,500	$ -	$ 450	$ -	$ 1,500	$ 450	$ 1,950
Item 3: Miscellaneous Lab Supplies	$ -	$ 1,000	$ -	$ 300	$ -	$ 1,000	$ 300	$ 1,300
Subtotal	$ -	$ 5,000	$ -	$ 1,500	$ -	$ 5,000	$ 1,500	$ 6,500
Travel (State number of trips and estimated cost/trip)								
Trip 1: Raw Materials Collection (2 trips)	$ -	$ 2,000	$ -	$ -	$ -	$2,000	$0	$2,000
Trip 2: Field Produced Materials Collection (4 trips)	$ -	$ -	$ -	$ 3,000	$ -	$2,000	$1,000	$3,000
Trip 3:								
Subtotal	$ -	$ 2,000	$ -	$ 3,000	$ -	$4,000	$1,000	$ 5,000
Communications (Printing is required)								
Printing (8 printed final reports are required)	$ -	$ -	$ -		$ 782	$ -	$ 782	$ 782
Other: Printing of Project Memorandum and Presentation Slides	$ -	$ -	$ 500	$ -	$ -	$ 500	$ -	$ 500
Subtotal	$ -	$ -	$ 500	$ -	$ 782	$ 500	$ 782	$ 1,282
TOTAL DIRECT COSTS	**$ 12,963**	**$ 42,734**	**$ 21,376**	**$ 55,902**	**$ 40,936**	**$ 106,157**	**$ 67,754**	**$ 173,911**
TOTAL INDIRECT COSTS (15% TDC)	**$ 1,944**	**$ 6,410**	**$ 3,206**	**$ 8,386**	**$ 6,141**	**$ 15,924**	**$ 10,163**	**$ 26,087**
Fixed Fee if Applicable								**$ -**
TOTAL CONTRACT COST	**$ 14,907**	**$ 49,144**	**$ 24,582**	**$ 64,288**	**$ 47,077**	**$ 122,081**	**$ 77,917**	**$ 199,998**

NOTES: *Year 1 starts with the date of the contract and ends 18 month after the start date.

Budget Justification

1. **Staff Benefits**
    a. **Fringe Benefit Rates:** All fringe benefit rates included in the budget are in accordance with the current rates established by the UW-Madison Office of Research and Sponsored Programs. More information is available at (https://www.rsp.wisc.edu/rates/index.html).
    b. **Tuition Remission:** UW-Madison Office of Research and Sponsored Programs Notice 2006-3 requires an annual tuition remission of $8000/yr. for graduate students assigned to the project. The proposed budget includes tuition remission for a total of three semesters.

2. **Computer Services - $2000 (1% of project budget)**
    a. These services are related to the purchase of new scanners or other equipment to support the use of the $IPas^2$ software to conduct planar imaging of the samples collected for the project.

3. **Materials and Supplies - $6,500 (3.25% of project budget)**
    a. **Containers and Shipping:** The proposed study requires sampling of raw material, field produced material, and field cores. A total of $3,250 was allocated to procure sampling containers and/or cover the cost of shipping from project sites and quarries to the UW-MARC lab.
    b. **Materials for Performance Test Sample Preparation:** The proposed mixture performance tests require cutting and coring of laboratory compacted samples to meet specific test geometries. Performance testing also requires instrumentation of samples. A total of $1,950 was budgeted for procurement of core bits, saw blades, sample targets, and glue for instrumentation.
    c. **Miscellaneous Lab Supplies:** A total of $1,300 was budgeted for the purchase of miscellaneous laboratory supplies. These costs are related to preparation of binder or mixture samples and subsequent quality testing. Specific examples include quart and gallon cans for binder storage, solvents for cleaning, and bags for evaluation of mixture density using the Corelok device.

4. **Travel - $5000 (2.5% of project budget)**
    a. Funds were budgeted for vehicle rental and other travel expenses associated with collection of raw or field produced materials. Based on the amount budgeted, a minimum of six trips to field locations are possible, two trips to sample raw materials from quarries and four trips to project locations. Expenses include vehicle rentals and reimbursements for meals and hotel stays. If possible, overnight trips will be avoided. All travel funds will be expended in accordance with UW Madison Accounting Services policies (http://www.bussvc.wisc.edu/acct/policy/travel/trpol.html). Travel related to attendance at TOC meetings based in Madison will not be charged to the project.

5. **Printing - $1281 (< 1% of project budget)**
    a. This line item includes printing costs associated with all project deliverables, including the interim project memorandum, draft/final reports, and presentations. Sufficient budget was reserved for printing of any other materials as requested by the TOC during the project.

7. Qualifications of the Research Team

Hussain U. Bahia – *Principal Investigator*

Dr. Bahia received his Ph.D. degree in the area of Pavement Materials and Design from the Pennsylvania State University in 1991. He joined the faculty at the University of Wisconsin-Madison in 1996 to teach and conduct research in the area of pavement materials and design. Prior to joining the UW faculty he served as the Director of Research and Engineering Services of the Asphalt Institute in 1995- 1996. He also served for four years after earning his Ph.D. on the faculty of Penn State University from 1991 to 1994.

He has served as the PI or co-PI on several Wisconsin DOT projects (more than ten major studies), projects with the FHWA (four major studies), and numerous projects funded by private industry (more than twenty studies). He is has served as the PI for the NCHRP 9-10 project from 1996 to 2000 and the NCHRP 9-45 project from 2007 to 2011. Dr. Bahia also served as a member of the NCHRP project panels for project 9-19 and project 9-23. In addition to technical involvement with WisDOT and FHWA, Dr. Bahia served as the Technical Director of WHRP from 2004 –

2012 and is thus aware of the mission of the WHRP program and experienced in administration of projects funded by WHRP.

Andrew Hanz – *Researcher*

Dr. Hanz earned his Ph.D. degree in May 2012 in the area of pavements and materials from the University of Wisconsin-Madison. The topic of his dissertation was quantifying the impacts of use of Warm Mix Asphalt (WMA) on construction and in-service performance. He is currently a researcher for the Modified Asphalt Research Center at the University of Wisconsin-Madison. Prior to earning his degree, Dr. Hanz has served as the project lead for work elements related to sustainable mixes for the Asphalt Research Consortium project sponsored by FHWA since December of 2006. Dr. Hanz also has experience in research program management and oversight, serving as the Program Manager for the Wisconsin Highway Research Program from 2006 - 2012. This role required participating in development, evaluation, and oversight of $1 million of research funded annually by WisDOT in the areas of rigid pavements, flexible pavements, structures, and geotechnics. Similar to Professor Bahia, the experience with the WHRP program allowed Dr. Hanz to develop an understanding of the goals of WHRP and the administrative requirements related to WHRP research project. He has recently been appointed as the academic representative to the WHRP Steering Committee and is also a member of ASCE, AAPT, and ISAP.

Pouya Teymourpour – *Research Assistant*

Mr. Teymourpour received his Bachelor of Science degree in Civil Engineering in 2007 from Sharif University of Technology (SUT) where he got his Masters in Road and Highway Engineering in 2010. During his Master period in SUT he worked on experimental analysis of modified asphalt binders and mixtures with focus on Rutting evaluation. In January of 2011, Mr. Teymourpour joined the UW-MARC group, receiving his degree in Master of Science degree in December of 2012 and pursuing his Ph.D. degree currently which is expected to be in Fall of 2014. Mr. Teymourpour's Master of Science thesis involved the investigation of the role of binder modification and initial aggregate structure in the laboratory responses of asphalt mixtures toward a performance based mix design procedure by means of a set of laboratory experiments and numerical simulations. During his masters time he also worked on understanding the mechanisms of aggregate structure formation during compaction and what factors influence aggregate structure which resulted in a paper titled, "Effect of Particle Mobility on Aggregate Structure Formation," which received the Walter J. Emmons Award for the best paper presented at the 2013 Association of Asphalt Paving Technologists Annual Meeting. Mr. Teymourpour's Doctoral dissertation is about using mastic characterization to predict asphalt mixture low temperature cracking behavior which through experimental and numerical analysis is trying to move toward mix design for asphalt mixtures based on their performance to resist better the thermal cracking. Mr. Teymourpour has been involved tremendously in different work elements of the Asphalt Research Consortium project sponsored by FHWA since 2011. Mr. Teymourpour has several publications and invited presentations from the Association of Asphalt Paving Technologists (AAPT), International Society of Asphalt Pavement (ISAP) and Transportation Research Board (TRB) related to his thesis work.

Erik Lyngdal – *Research Assistant*

Mr. Lyngdal received his Bachelor of Science degree in Civil Engineering in 2013 from University of Wisconsin-Madison with focus on structural engineering and design of materials specially wood, steel and pavement. During his Bachelor he won the first place of the WAPA competition award which is an annual asphalt pavement design competition hosted by the Wisconsin Asphalt Pavement Association. Mr. Lyngdal is joined currently a graduate student at UW-MARC studying toward his Master of Science while he has been the laboratory manager since May 2014. His research is focused on finding solutions to recycling asphalt pavements and understanding effects of asphalt polymer modification on conventional Hot Mix Asphalt. Mr. Lyngdal has also been working on conducting research asphaltic materials for ongoing research projects at the Modified Asphalt Research Center where his objective to aim to increase understanding of asphalt as a material, connect field performance to laboratory testing procedures, and create solutions to problems facing the industry.

8. Other Commitments of the Research Team

Table 8-1: Other Commitments of the Research Team

Research Team Commitments			Percentage of Time	
Team Member	**Role**	**Activity**	**Committed**	**Available**
Professor Hussain Bahia	Principal Investigator	Activity 1: Dept. of Civil and Environmental Engineering	35%	
		Activity 2: Asphalt Research Consortium, FHWA, 12/06 - 06/14	15%	
		Activity 3: Pooled Fund Study - Modified Binder Testing Guidelines - Phase II, 08/12-11/13	5%	
		Activity 4: Modified Asphalt Research Center	10%	
		Total	**65%**	**35%**
Pouya Temourpour	Research Assistant	Activity 1: Asphalt Research Consortium, FHWA, 12/06-06/14.	20%	
		Activity 2: Ph.D. Dissertation	20%	
		Activity 3: Pooled Fund Study - Modified Binder (PG+) Specsifications, 09/14-09/16	20%	
		Total	**60%**	**40%**

9. Equipment and Facilities

The Asphalt research facilities of the College of Engineering are part of the Wisconsin Structures and Materials Laboratory. The facilities are housed within the Engineering building on the main campus in Madison. The facilities total area dedicated for asphalt testing is approximately 1600 square feet. All necessary equipment required for complete SuperPave analysis of asphalt cements, asphalt mixtures volumetric design, and mixture performance testing are available at the asphalt laboratory. The following sections include details of equipment available.

Asphalt Binder Laboratory

The Asphalt Binder Laboratory has state-of-the-art SuperPave testing equipment to characterize asphalt binders using both standard and non-standard tests. Specifically, the laboratory has the ability to perform performance-graded asphalt binder specification testing (AASHTO M 320) and also conduct advanced rheological and damage characterization of asphalts and emulsion residues. The laboratory also contains equipment for new tests recently developed at UW-MARC to modify asphalts with numerous types of additives (polymer, polyethylene, etc) or by foaming. Specific examples of the equipment available include: High and low shear mixers for modifying binders with a wide range of modification types, Four research grade DSRs, including a state-of-the-art Anton-Paar MCR301, Bitumen Bond Strength Test to strength of the bond at the asphalt/aggregate interface, Single Edge Notched Bending (SENB) test to evaluate the low temperature fracture properties of asphalt binders and mortars.

Asphalt Mixture Laboratory

The Asphalt Mixture Laboratory includes all equipment necessary to conduct standard SuperPave volumetric mixture design procedures and to characterize mixture performance. For preparation of samples and evaluation of mixture behavior during construction the laboratory is equipped with two SuperPave Gyratory compactors in addition to standard measures, these machines are capable of measuring the shear resistance of mixtures using either internal or external devices. A Marshall compactor is also available to provide mix design support to those who have not yet adopted SuperPave mix design protocols. For mixture characterization the lab maintains two servo-hydraulic testing machines for performing testing according to SuperPave and mechanistic design procedures. One of the testing systems is equipped with an environmental chamber and allows measuring the low and intermediate Indirect Tension (IDT) mixture testing, repeated creep, and dynamic modulus. The temperature control allows maintaining sample temperatures from -40°C to 80°C. The lab also includes an instrumented environmental chamber to evaluate the volume change of asphalt mixtures at low temperatures as a means to evaluate potential for thermal cracking. In addition to the standard Superpave test equipment, the UWM laboratories are equipped with the following specialized testing equipment:

- Compactability and mix stability using the Gyratory Pressure Distribution Analyzer (GPDA)
- Two research grade SuperPave gyratory compactors, including a state-of-the-art Troxler 5850 capable of measuring internal shear
- Universal Testing Machine capable of conducting the following tests:
  - AASHTO T321: Determining the Fatigue Life of Compacted Hot Mix Asphalt (HMA) Subjected to Repeated Flexural Bending
  - AASHTO T322: Creep Compliance and Strength of HMA using Indirect Tension Testing.
  - AASHTO T342: Standard Method for Determining Dynamic Modulus of Hot Mix Asphalt Mixtures
  - AASHTO TP79: Standard Method of Test for Determining the Dynamic Modulus and Flow Number for Hot Mix Asphalt (HMA) Using the Asphalt Mixture Performance Tester (AMPT)
- Hamburg Wheel Tracking Machine that meets requirements of AASHTO T324
- Thermal cracking resistance and glass transition of bituminous mixtures using the Asphalt Thermal Cracking Analyzer (ATCA).
- Planar imaging/Aggregate Structure Analysis Software (iPas)

10. Technician and Laboratory Certification

UW-MARC laboratories are not AMRL certified, however the center maintains annual calibration of testing equipment and participates quarterly in the Combined States Group Round Robin Testing Program and also leads round robin testing of asphalt binders and mixtures for the Rocky Mountain User Producers Groups. Members of the research team have published numerous papers and developed training courses related to the design and compaction of asphalt mixtures. Upon notice of award the research team is more than willing to share this information with the TOC membership to determine if the products produced to date meet the equivalent certification requirement desired by the TOC. If it is deemed necessary, the research team will pursue the HTCP certifications at no cost to the project. Specifically, the following certification courses will be taken: HMA Mix Designer (HMA-MD): Andrew Hanz, HMA Technician (HMA-IPT): Nima Roohi.

11. References

1. Bonaquist, R. Evaluation of Flow Number (Fn) as a Discriminating Mixture Property. *Wisconsin Highway Research Program Project 0092-09-01,* Wisconsin Department of Transportation, Madison, WI, 2012.

2. Bonaquist, R**.,** Wisconsin Mixture Characterization Using the Asphalt Mix Performance Tester (AMPT) on Historical Aggregate Structures. *Wisconsin Highway Research Program Project 0092-08-06.* Wisconsin Department of Transportation, Madison, WI , 2010.

3. Marasteanu, M., Buttlar, W., Bahia, H., Williams C., Investigation of Low Temperature Cracking in Asphalt Pavements - National Pooled Fund Study - Phase II. Minnesota Department of Transportation, St. Paul, MN, 2012.

4. Schmitt, R. Faheem, A., Al-Qadi, I. Investigation and Development of a Non-Destructive System to Evaluate Critical Properties of Asphalt Pavements during the Compaction Process. *Wisconsin Highway Research Program Proejct 0092-11-01.* Wisconsin Department of Transportation, Madison, WI, 2013

5. Li, X. Gibson N., Using Small Scale Specimens for AMPT Dynamic Modulus and Fatigue Tests. In Asphalt Paving Technology Vol. 82., Journal of the Association of Asphalt Paving Technologists, Association of Asphalt Paving Technologists, 2013, pp. TBD.

6. Roohi, N., L. Tashman, H.U. Bahia. "Characterization of Mixture Rutting Performance Using 2-D Imaging Techniques and Internal Structure Parameters." In Asphalt Paving Technology Vol. 80, Journal of the Association of Asphalt Paving Technologists. Association of Asphalt Paving Technologists, pp. 109-138.

7. Teymourpour, P., Hacker, S., Bahia, H. Role of Asphalt Modification in Acheiving Better Aggregate Packing and Performance.: Canadian Technical Asphalt Association, 2013, Vol. TBD.

8. Guler, M., Bahia, H., Bosscher, P., Plesha, M. Device for Measuring Shear Resistance of Hot Mix Asphalt in the Gyratory Compactor. , In Transportation Research Record Vol. 1723, Journal of the Transportation Research Board, Transportation Research Board of the National Academies Washington D.C., 2000, pp. 116-124.

9. Faheem, A., Bahia, H.U. Using the Superpave Gyratory Compactor to Estimate Rutting Resistance of Hot Mix Asphalt. *Transportation Research Circular: Practical Approaches to Hot Mix Asphalt Mix Design and Production Quality Control Testing Vols. E-C124.*. The Transportation Research Board of the National Academies, Washington D.C., December 2007.

10. Bonaquist, R. Ruggedness Testing of the Dynamic Modulus and Flow Number Tests with the Simple Performance Tester. *NCHRP Report 629.* Transportation Research Board, Washington D.C., 2008.

11. Bonaquist, R. Effects of Recovered Binders from Recycled Shingles and Increased RAP Percentages on Resultant PG. *Wisconsin Highway Resarch Program Project 0092-10-06.* Wisconsin Department of Transportation, Madison, WI, 2011.

12. Swiertz, D., H.U. Bahia. Test Method to Quantify the Effect of RAP and RAS on Blended Binder Properties without Binder Extraction. *Journal of the Canadian Technical Asphalt Association***.** Canadian Technical Asphalt Association, Quebec City, Quebec, 2011, pp. 43-60.